NATIONAL WATER-QUALITY ASSESSMENT PROGRAM: WATER QUALITY IN SURFICIAL AQUIFERS IN TWO AGRICULTURAL AREAS IN GEORGIA, ALABAMA, AND FLORIDA

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ABSTRACT

As part of the U.S. Geological Survey National WaterQuality Assessment Program, water samples were collected from 61 shallow monitoring wells located adjacent to farm fields in parts of southwestern Georgia, southeastern Alabama, and northern Florida in 1993 and 1994. Nitrate concentrations in water from 15 percent of the wells exceeded the U.S. Environmental Protection Agency (EPA) drinking-water standard of 10 milligrams per liter as N. These exceedences were not widespread and the surficial aquifers are not used as a source of drinking water. Trace concentrations of a total of six commonly used pesticides were detected in water samples from 44 percent of the wells, but no concentrations exceeded drinking-water standards. Highest measured concentrations of the herbicides alachlor and atrazine were 28 and 14 percent of EPA drinkingwater standards, respectively. Volatile organic compounds were rarely detected in shallow ground water and did not exceed EPA drinking-water standards. Water from 44 wells was analyzed for radon, a naturally occurring radioactive constituent. Radon concentrations in water from 67 percent of these wells exceeded the proposed drinking-water standard of 300 picocuries per liter.

INTRODUCTION

The Apalachicola-Chattahoochee-Flint (ACF) River basin study unit, in Georgia, Alabama, and Florida and the Georgia-Florida (GAFL) Coastal Plain study unit, in Georgia and Florida (fig. 1), are among the first 20 study units in which work began in 1991 as part of the National Water-Quality Assessment (NAWQA) Program of the U.S. Geological Survey (USGS). The results of the agricultural land-use study components of the ground-water sampling programs for the ACF and GAFL NAWQA studies are presented in this paper. The purpose of the ACF and GAFL agricultural land-use studies is to describe the chemical quality of shallow ground water that underlies agricultural land in the southern Coastal Plain physiographic province. The surficial aquifer was selected for sampling, rather than deeper aquifers that are used for public, domestic, and irrigation water supply, because the surficial aquifer is the uppermost water-bearing zone, and is generally most susceptible to contamination. Degradation of water quality in the surficial aquifer may serve as an early warning of potential contamination of more extensively used deeper aquifers.

This report presents major ion, nutrient, pesticide, volatile organic compound, and radon concentration data from shallow ground-water samples collected as part of the ACF and GAFL agricultural land-use studies. In both studies, ground-water samples were collected in early spring 1994 (moderate to high water-table conditions). Ground-water samples also were collected in late summer 1993, as part of the ACF agricultural land-use study (low water-table conditions), and in late summer 1994, as part of the GAFL agricultural land-use study (moderate to high water-table conditions because of an unusually wet year).

AGRICULTURAL LAND-USE STUDY DESIGNS

The ACF and GAFL agricultural land-use study areas (fig. 1), about 6,800 mi^2 and 1,335 mi^2, respectively, have the highest percentage of row crop land use in the ACF and GAFL study units. Agricultural land, predominantly row crops, was subdivided into a predetermined number of equal-sized areas to insure spatially distributed sampling within each study area. A stratified, random-sampling procedure (Scott, 1990) was used to select agricultural fields within each equal-sized area. These random locations were field checked to verify agricultural land use. Well locations at 38 sites in the ACF study area and 23 sites in the GAFL study area were selected adjacent to agricultural fields. Within the ACF study area, the locations of about half the monitoring wells were selected at a uniform spatial density within the study area and the other locations were selected at a greater spatial density within two small watersheds. Reference wells were installed at four sites in pine forests in the ACF study area (two Georgia State Parks, one Georgia Wildlife Management Area, and one Ecological Research Center) to evaluate shallow ground-water quality in areas less likely to be directly affected by agricultural land use. Wells throughout the study areas were constructed and water samples collected and processed using protocols described by Wayne Lapham, Franceska Wilde, and Michael Koterba (U.S. Geological Survey, written commun., 1992). Monitoring wells less than 80 feet in depth were completed tapping shallow, surficial aquifers in the undifferentiated overburden.

DESCRIPTION OF AGRICULTURAL LAND-USE STUDY AREAS

Sediments in the undifferentiated overburden consist of clays, sandy clays, and sands and are generally younger in the GAFL than the ACF study area. In the ACF study area these sediments are mostly derived from weathered carbonates; in contrast, the sediments in the GAFL study area are mostly fluvial deposits (Jim Miller, U.S. Geological Survey, oral commun., 1995).

Agriculture is the predominant land use in the ACF and GAFL agricultural land-use study areas, comprising 54 and 64 percent, respectively (Anderson and others, 1976). About 40 percent of the ACF study area is forested and 4 percent is wetlands. About 28 percent of the GAFL study area is forested and 6 percent is wetlands. Urban and other land uses make up the remaining areas. Major crops grown in the ACF and GAFL study areas are peanuts, corn, and cotton. Soybeans, sorghum, millet, rye, wheat, and truck vegetables also are grown, to a lesser extent, in these areas.

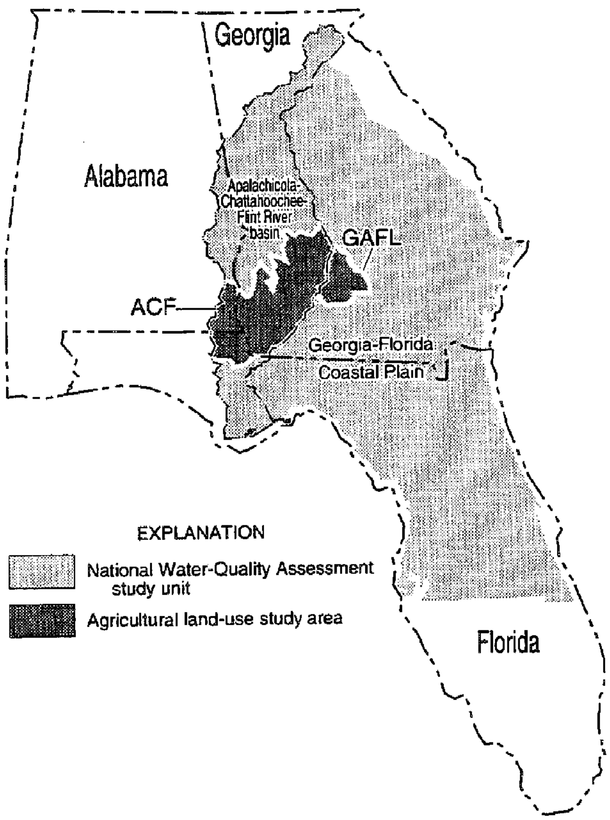

Figure 1. Location of Apalachicola-Chattahoochee-Flint (ACF)River basin and Georgia-Florida (GAFL) Coastal Plain National-Water Quality Assessment study units and the ACF and GAFL agricultural land-use study areas.

During the summer of 1993, fields adjacent to ACF study area wells were planted in peanuts (58 percent), corn (29 percent), and cotton (13 percent). During the early spring 1994 sampling period, adjacent fields were planted in winter wheat and other small grains or were being prepared and planted in row crops. Fields adjacent to the GAFL wells during the 1993 and 1994 sampling periods were planted in peanuts (46 and 60 percent, respectively), corn (36 and 15 percent, respectively), and cotton (18 and 25 percent, respectively). Approximately one-fourth to one-third of adjacent fields were irrigated in the ACF study area, whereas only one adjacent field was known to be irrigated in the GAFL study area.

Rates of fertilizer application vary depending on local soils, current and previous crops, and crop-management practices. Of the crops commonly grown in the ACF and GAFL study areas, corn requires the heaviest application of nitrogen fertilizer. Estimated average nitrogen fertilizer-application rates range from 125 to 220 lb/acre for corn, about 40 lb/acre for cotton, and generally lesser rates for soybeans and peanuts (W. Segars, Cooperative Extension Service Agronomist and Water Quality Coordinator, written commun., 1994).

Pesticides are commonly used on agricultural land in the ACF and GAFL study areas for weed and insect control. The most commonly used pesticides in Georgia are alachlor, atrazine, MSMA, metolachlor and 2,4-D (Gianessi and Puffer, 1990). A multi-analyte method was used by the USGS laboratory to measure 47 pesticides commonly used throughout the United States. USGS laboratory methods do not include some commonly used pesticides, such as paraquat, glyphosate, DSMA, MSMA, and several chlorophenoxy herbicides. Therefore, it should not be assumed that these pesticides are not applied in the basins or are not present in the water.

SHALLOW GROUND-WATER QUALITY

On-site measurements of specific conductance, pH, dissolved oxygen, and alkalinity are generally higher in water from surficial aquifers in the ACF than in the GAFL study areas (fig. 2a). Depths to water below land surface are significantly greater in monitoring wells in the ACF than in the GAFL study areas. Higher specific conductance is consistent with greater depths to water in the ACF study area and imply longer travel times, longer travel distances, and/or more soluble soil minerals in the ACF than in the GAFL study area. Higher pH and alkalinity in the ACF study area are indicative of carbonate dominated ground water in the surficial aquifer. In the GAFL study area, median pH was 4.5 with little or no alkalinity.

Calcium concentrations were significantly higher in the ACF than in the GAFL study area; while magnesium, potassium, chloride, and nitrate concentrations were higher in the GAFL study area (fig. 2b). Higher calcium concentrations in the ACF study area result from increased calcium carbonate content in the overburden sediments. Lower calcium concentrations observed in the GAFL study area may be due to predominantly silicious surficial materials. Higher potassium and nitrate concentrations in the GAFL study area may be the result of a higher percentage of row-crop agriculture and higher fertilizer application rates. Shallow ground water is predominately calcium bicarbonate water in the ACF study area and sodium chloride water in the GAFL study area.

Nitrate concentrations in water from 2 of 38 wells in the ACF study area and 7 of 23 wells in the GAFL study area (fig. 3) exceeded the U.S. Environmental Protection Agency (EPA) drinking-water standard of 10 mg/L as N (EPA, 1994). Sources of nitrate generally are fertilizer, human and animal wastes, and atmospheric deposition. Nitrate concentrations in water from 11 of 38 wells in the ACF study area and 11 of 23 wells in the GAFL study area ranged from 3 to 10 mg/L as N, indicating probable human influence (Madison and Brunett, 1985, p. 95). Water from 25 of 38 wells and the 4 reference wells in the ACF study area, and 5 of 23 wells in the GAFL study area had nitrate concentrations less than 3 mg/L as N, indicating natural conditions to possible human influence. There was no correlation between crops grown on fields adjacent to monitoring wells and nitrate concentrations in ground water. However, nitrate concentrations were inversely related to depth to water and well depth in the GAFL study area. Ammonia, nitrite, phosphorus, and orthophosphorus concentrations in water were generally at or below minimum-detection limits in both study areas.

Pesticide (herbicide and insecticide) concentrations in shallow ground water did not exceed EPA drinking-water standards. The highest measured concentrations of alachlor and atrazine were 28 and 14 percent, respectively, of the standards. Trace concentrations of a total of three herbicides and two insecticides were detected in water from 47 percent of the wells in the ACF study area and a total of four herbicides were detected in water from 39 percent of the wells in the GAFL study area (table 1, fig. 4). Pesticides were not detected in water from the 4 reference wells in the ACF study area.

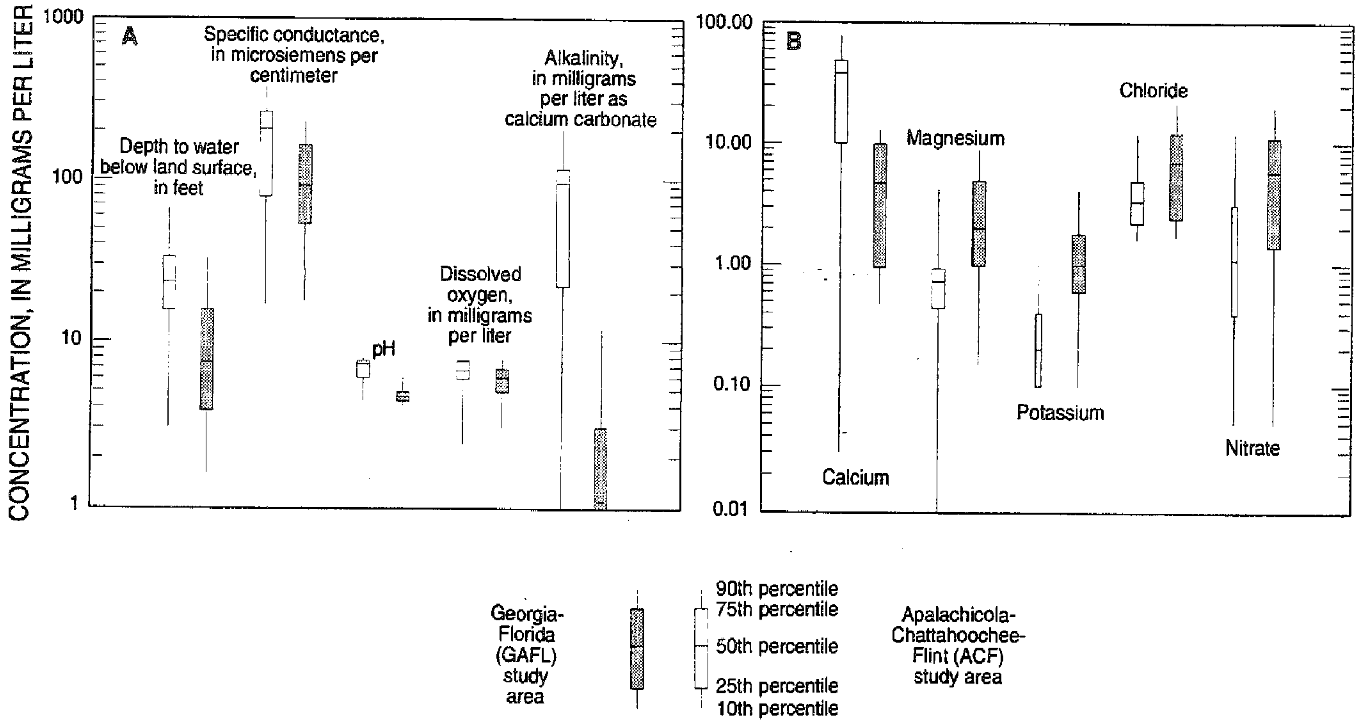

Figure 2. Distribution of (A) water levels, specific conductance, pH, dissolved oxygen, and alkalinity and (B) calcium, magnesium, potassium, chloride, and nitrate in shallow monitoring wells in the ACF and GAFL study areas.

Volatile organic compounds (VOC) were rarely detected in shallow ground water in agricultural areas in the ACF and GAFL study areas and where detected, did not exceed EPA drinking-water standards. Possible sources of VOC in agricultural areas are soil fumigants, inert ingredients in liquid-pesticide formulations, and leaking fuel-storage tanks. VOC were detected in water samples from just 1 of 33 wells sampled in the ACF study area. Water from the well contained toluene (0.5 µg/L), psuedocumene (0.4 µg/L), p-isopropyltoluene (0.3 µg/L), xylene (0.3 µg/L), and mesitylene (0.2 µg/L) in late summer 1993, and benzene (2.8 µg/L) in spring 1994. Water from all 23 wells in the GAFL study area was sampled for VOC in spring 1994 and water from 13 of these wells was resampled for VOC late summer 1994. Toluene was detected in water from two wells (1.0 and 0.4 µg/L), benzene was detected in water from one well (0.7 µg/L).

Radon concentrations in shallow ground water exceeded the proposed EPA drinking-water standard of 300 picocuries per liter (pCi/L) (U.S. Environmental Protection Agency, 1994) in 67 percent of all samples. Radon is a gas dissolved in ground water and is produced by the radioactive decay of the naturally occurring element radium. In homes relying on ground-water supply, radon may degas causing an increased risk of lung cancer. Radon concentrations in water from wells in the ACF study area ranged from less than 80 to 1,800 pCi/L, and from 530 to 1,400 pCi/L in the GAFL study area. The measured radon concentrations are not unusually high relative to concentrations found in other areas of the United States (from about 100 to nearly 3 million pCi/L, Otton and others, 1993). The median radon concentration in the GAFL study area (1,000 pCi/L) was significantly higher, based on the Kruskal-Wallis test (Helsel and Hirsch, 1992) than the median concentration in the ACF study area (250 pCi/L).

Table 1. Pesticides in shallow ground water and their relation to U.S. Environmental Protection Agency drinking-water standards
[MCL, maximum contaminant level; HA, health advisory; mg/L, microgram per liter]

Chemical name	MCL[1/] (µg/L)	Lifetime HA[2/] (µg/L)	Number of agricultural wells with trace concentrations of pesticides measured		Highest measured concentration	
			ACF study area	GAFL study area	(µg/L)	Percent of MCL[1/]/HA[2/]
			Herbicides			
Alachlor	2	--	3	2	0.55	28/--
Atrazine	3	3	11	1	0.42	14/14
Metolachlor	--	100	8	8	1.0	--/<1
Metribuzin	--	200	0	1	0.037	--/<1
			Insecticides			
Fonofos	--	10	1	0	0.009	--/<1
Malathion	--	100	1	0	<0.014[3/]	--/<1

[1/] Maximum contaminant level (MCL) is the maximum permissible level of a contaminant in water that is delivered to any user of a public water system (U. S. Environmental Protection Agency, 1994).
[2/] Lifetime health advisory (HA) is the concentration of a chemical in drinking water that is not expected to cause any adverse noncarcinogenic effects over a lifetime of exposure, with a margin of safety (U.S. Environmental Protection Agency, 1994).
[3/] Reported concentration is less than method detection level (MDL) reported from U.S. Geological Survey National Water Quality Laboratory.

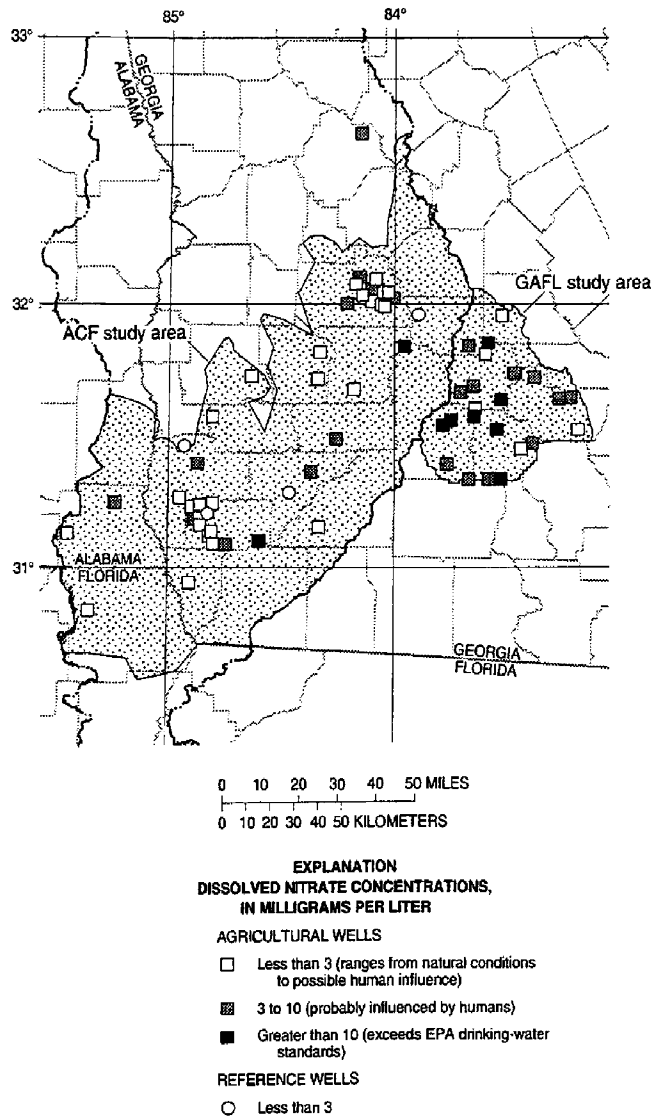

Figure 3. Nitrate concentrations in shallow ground water in the ACF and GAFL study areas.

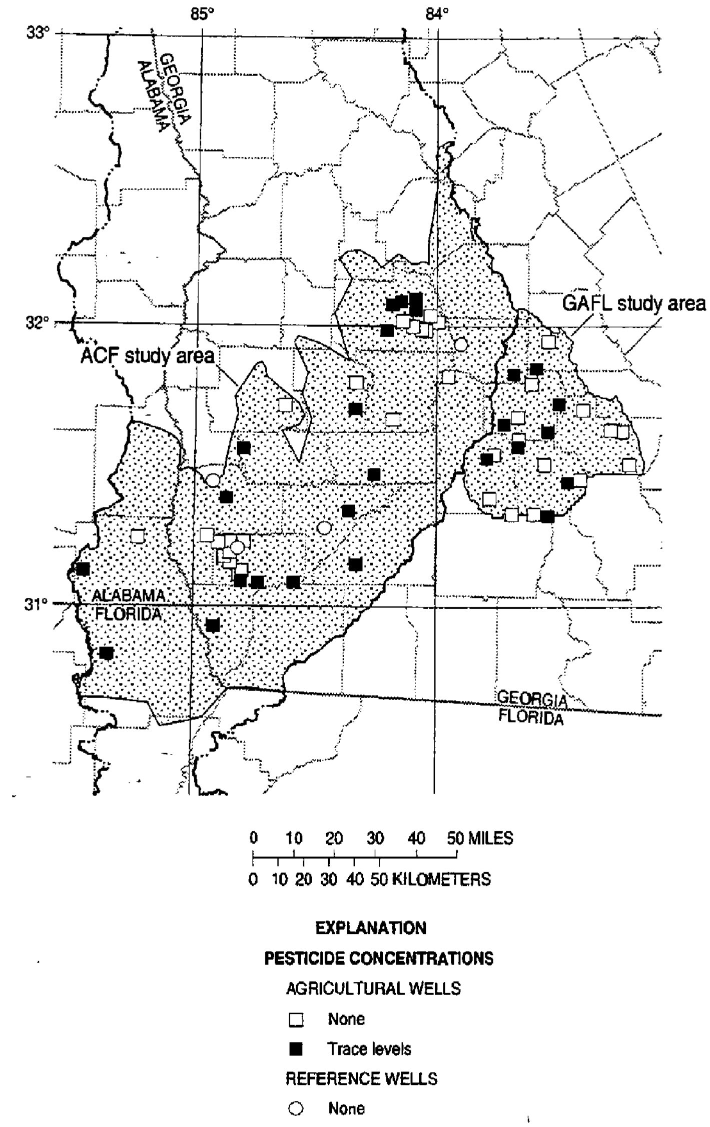

Figure 4. Pesticide concentrations in shallow ground water in the ACF and GAFL study areas.

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